ENGINEERING DIVISION

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Report No. T-107
(1963/7)

THE BRITISH BROADCASTING CORPORATION

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1. INTRODUCTION

On Saturday July 14th 1962 the G.P.O. made a request to the BBC that colour television signals be provided for an experimental transmission to the U.S.A. by means of the Telstar satellite. The signals were first required for the 60th pass of the satellite which was due at 10.30 p.m. on Monday July 16th.

2. TECHNICAL ARRANGEMENTS

The American colour television standard devised by the National Television System Committee operates on 525 lines, 60 fields per second and requires a video bandwidth of 4·2 Mc/s. The subcarrier for the chrominance signal in the composite waveform has a frequency of 3·579545 Mc/s ± 10 c/s, i.e., about ± 0·0003%; the importance of this will be mentioned later.

It was already known that the existing link between Goonhilly Down and Television Centre had a performance inadequate to handle signals of the television standard indicated above and it was therefore decided that the only way of producing the required signals satisfactorily would be to take the necessary picture-originating equipment to Goonhilly Down. Accordingly work was started immediately to modify available equipment to operate on the American standard. In Research Department, a Cintel 2 in × 2 in (5 cm × 5 cm) colour slide scanner, recently delivered by the manufacturer, was adjusted to operate on 525 lines, 60 fields per second and in Designs Department a 625 lines, 50 fields per second NTSC-type coder, which was under development, was modified to similar standards. These two main items of equipment together with a Bush "R.G.B." monitor, an R.C.A. Victor colour receiver and a Hewlett-Packard counter were all dispatched by road on the Sunday morning. It is fortunate that Designs Department were in possession of an R.C.A. Victor receiver since this was a typical commercial American colour receiver as used in many American homes and its performance could, therefore, be considered to be representative of the results which might be obtained under transatlantic broadcast conditions.

By the afternoon of Monday July 16th the slide-scanning and coding equipment had been installed at Goonhilly Down and was producing satisfactory colour signals. These were to be passed to the G.P.O. equipment at video frequency and the received signals from the Telstar circuit were to be passed back by the G.P.O. engineers at video frequency. In order to use the R.C.A. Victor receiver as a monitor of the pictures it was therefore necessary to remodulate the signal on to a suitable carrier by means of a low power r.f. modulator. A simple switching circuit was constructed for changing the input of this modulator-receiver combination from the transmitted signal to that received from Telstar, using the video signals referred to above.

A signal relayed by the satellite is received on both sides of the Atlantic. At the sending station it is demodulated and displayed in the same way as an incoming transatlantic signal and this, of course, gives a very valuable check on the quality of the transmission. Much of the information from the experimental transmission and the most revealing photographs were, in fact, obtained from the so-called "loop circuit" provided by transmission to Telstar and simultaneous reception of Telstar's return signal. In this case the path length between the Goonhilly transmitter and receiver was subject to maximum variation and at the beginning of the pass was some 14,000 miles (22500 km), dropping to about 3,500 miles (5630 km) at the point where the American station switched off the Telstar transmitter before losing contact.

No attempt will be made here to describe the technical details of the Telstar satellite or the ground stations in America, France and Great Britain which are associated with the project since, no doubt, there will soon be a publication giving much more authoritative information than that which is known at present.

3. EXPERIMENTAL TRANSMISSIONS

A brief diary is given below of the four experimental transmissions in which the BBC co-operated with the G.P.O. engineers in transmitting colour pictures across the Atlantic.

3.1. Pass No. 60 - July 16th 1962 - commenced 22.30 hours B.S.T., finished 22.55 hours B.S.T.

This was the first occasion on which high-definition colour television signals were transmitted across the Atlantic Ocean. Contact was made by Goonhilly Down station when the satellite was at an elevation of about 2° and the standard pulse-and-bar signals were transmitted. After a short period for checking, electronic colour bars were transmitted to permit the American engineers to align their colour receiving equipment. Following this a specially prepared colour caption card was transmitted which bore the words "BBC Experimental Colour Transmission" and overprinting which read "British Post Office, by Telstar Satellite". This was successfully received at Andover, Maine. The Americans apparently had no difficulty in locking their receiver to the incoming signals and they confirmed immediately that picture quality was good. In accordance with the arrangements previously made with Mr. R.W. White, Director of Experiments at Goonhilly Down, a series of the well-known SMPTE colour test slides was then transmitted, returning to the identification caption after every 3rd slide.

During this period an item in the 10.30 p.m. BBC Television News Bulletin included an outside broadcast from the control room at Goonhilly Down and British viewers were able to see in black and white the colour monitor displaying the picture as it was being returned from Telstar.

The impression of the picture quality after transmission over the "loop circuit" to Telstar and return was that flesh tones were too pink and there was in fact a slightly pink overall cast to the pictures. The red channel of the Cintel slide scanner was very noisy and it was thought that this might be causing an adverse effect on the general balance of the coded signals, although the colours appeared to be correct on the R.G.B. monitor. Comparison of the outgoing and returning pictures

also showed that there was a slight tendency to an additional colour error and the impression obtained was that the received picture had a slight overall cast of the same hue as the predominant colour in the original. The effect was, however, quite small. The electronically generated colour bar signal was used as a means of providing an interval signal while changing slides in the scanner; the Americans were examining by means of a Vectorscope the signal received and they later stated that they found the axes of the two chrominance signals to be correctly perpendicular to each other. At the conclusion of this broadcast the American comment was that the pictures were very good indeed, although "the people in the transmitted pictures appeared to be blushing slightly", but this was felt also to be true of the pictures as they were leaving Goonhilly.

3.2. Pass No. 61 - July 17th 1962 - commenced 01.27 hours B.S.T. finished 01.45 hours B.S.T.

During the two hours or so between this and the previous pass, the opportunity was taken to re-check the alignment of the colour slide scanner and the coding equipment; as the result of a number of minor adjustments the slight colour cast previously observed on the pictures had disappeared and the output of the equipment was of very high quality, comparable with BBC demonstrations given in the past to the C.C.I.R. After the preliminaries of pulse-and-bar and colour bar transmissions the series of SMPTE slides were again transmitted and this time both the "sent" and "received" (loop circuit) pictures appeared to be very satisfactory. There was again a very slight tendency for the predominant colour in each slide to give a slight cast of this colour to the whole of the received picture. The cause of this is not known but it may well be an effect produced only within the R.C.A. receiver in the presence of a rather noisy signal. This is supported by the fact that the effect was most noticeable at the extreme range of the loop circuit and seemed to be reduced as the Telstar satellite came nearer to Goonhilly Down.

At the end of this transmission the American comment was that the pictures were excellent. It is, in fact, possible that the pictures seen at Andover, Maine, were better than those seen in the control room at Goonhilly Down since the inexpensive R.C.A. receiver used there had a rather obvious phase error in the chrominance circuits. The difference between the "sent" and "received" signals was very small indeed and the impression was gained that the Telstar circuit, despite its very great path length, introduced very little degradation indeed to the colour signals.

At the conclusion of this very successful demonstration of the capability of the Telstar circuit the BBC engineers were asked to stay on for a further three days in order to co-operate in more experiments and to enable the Americans to arrange for a colour transmission from the U.S.A. to the U.K.

3.3. Pass No. 79 - July 19th 1962 - commenced 00.42 hours B.S.T., finished 01.05 hours B.S.T.

During the day-time on 17th and 18th July some experiments had been conducted to find a means of measuring the frequency change in the received chrominance subcarrier due to Doppler effect produced by the rapidly changing path length of the Telstar "loop" circuit. After achieving the main objective of sending colour

television pictures across the Atlantic it was considered that an attempt to obtain some experimental evidence of the significance of Doppler effect warranted most attention. Experiments were made with a search coil placed near the oscillator in the R.C.A. receiver and connected to the Hewlett-Packard counter; this enabled continuous monitoring of the frequency of the subcarrier oscillator in the receiver. With the receiver switched to the "sent" signal, the frequency of the subcarrier oscillator in the coding equipment could be measured but on switching the receiver to the signal being returned from Telstar the change in frequency indicated the magnitude of Doppler effect on the loop circuit.

The Telstar satellite contains a radio beacon operating on 4080 Mc/s and this beacon is in operation permanently so that the "Minitrack" stations around the world are able to plot its course accurately. The power of this radio beacon is small and therefore the receiver on each of the ground stations has a very narrow bandwidth, said to be 1 kc/s. It is therefore necessary for the ground station to know the magnitude of Doppler effect on each pass in order that tuning of their receiver to the beacon may be adjusted. The Doppler effect on the beacon signal transmitted from the Telstar satellite to the ground station is therefore computed for each pass. Our observations on the loop circuit from Goonhilly to Telstar and return, could therefore be related to the computed figures supplied by the Post Office engineers. The magnitude of Doppler effect on the loop circuit is, of course, more than that experienced over the more normal path of Goonhilly - Telstar - Andover, Maine, or the reverse. During pass No. 79 the usual series of pictures was transmitted and many measurements were made of the subcarrier frequency as returned by the Telstar satellite. Once again the Americans expressed themselves very pleased with the quality of the colour pictures as they received them.

3.4. Pass No. 88 - July 20th 1962 - commenced 00.20 hours B.S.T., finished 00.50 hours B.S.T.

This was the final colour television transmission experiment of the series and after the usual pulse-and-bar preliminaries, colour bars were received from Andover, Maine, followed by the same series of SMPTE colour slides that had been used in transmissions to Andover.

Throughout the reception of these pictures measurements were made minute by minute of the received subcarrier frequency and the pictures displayed by colour receiver were photographed using High Speed Ektachrome film. The American picture appeared to be de-saturated and in particular it was noticed that the reds in the scenes were of the familar "dried blood" appearance usually associated with coding errors. It was felt that these defects in the picture must have originated before the signal entered the satellite circuit.

Approximately half way through pass No. 88 the satellite link was reversed and Goonhilly Down once again transmitted pictures from the SMPTE series of slides. Further measurements of Doppler effect on the loop circuit were made and a number of pairs of photographs were taken of pictures sent to and returning from the satellite. An example is given in Fig. 1(a) and 1(b). At the conclusion of this broadcast the equipment was dismantled and made ready for the journey back to London.

(a) Sent to Telstar

(b) Received from Telstar

Fig. 1

4. COLOUR SUBCARRIER FREQUENCY MEASUREMENTS

Fig. 2 shows the variation in the frequency of the colour subcarrier after having passed around the Goonhilly - Telstar - Goonhilly loop circuit during pass No. 79. The magnitude of the Doppler effect upon frequencies transmitted via such a looped circuit must always be greater than that experienced when using the normal point-to-point satellite circuit. The bearing of the satellite from Goonhilly was found to vary only about two degrees during those passes described in this report, which means that the satellite's major component of velocity was acting almost wholly along the line of propagation to and from Goonhilly. From these facts it can be concluded that the errors in received subcarrier frequency shown in Fig. 2 are greater than any which could occur in practice over the normal satellite circuit. It will also be seen that close agreement exists between the measured frequencies and the values computed from the data applicable to the Telstar 4080 Mc/s beacon.

The conditions occuring during a transmission from Andover to Goonhilly are shown in Fig. 3, which illustrates the measured variation of the received subcarrier frequency during pass No. 88. In this case the absolute nature of the frequency scale is of no significance, because the precise value of transmitted frequency was not known - it was probably much too high. Two conclusions can be drawn from these results, however. First, the frequency of the received subcarrier is seen to decrease with time; this is due to the fact that, although during the pass the component of satellite's velocity towards Goonhilly was increasing, its component of velocity towards Andover was decreasing at a greater rate. It can be concluded, therefore, that the actual overall frequency shift between Andover and Goonhilly is less than that for the "looped" circuit of the type shown in Fig. 2. Secondly, if pass No. 88 represents typical circumstances, it follows that a suitable value of transmitted frequency could be chosen for a special broadcast so that the received colour subcarrier would lie within the NTSC tolerance of ± 10 c/s.

Doppler effect, of course, results from an expansion or contraction of the time scale during transmission, and all components of the waveform are equally affected. This means that the line and field frequencies, as well as the subcarrier

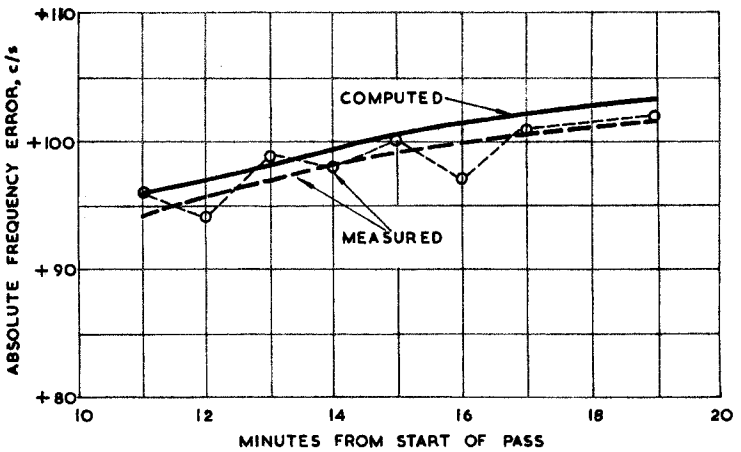

Fig. 2 - Goonhilly-to-Telstar satellite loop circuit. Error in frequency of received colour subcarrier during pass no. 79

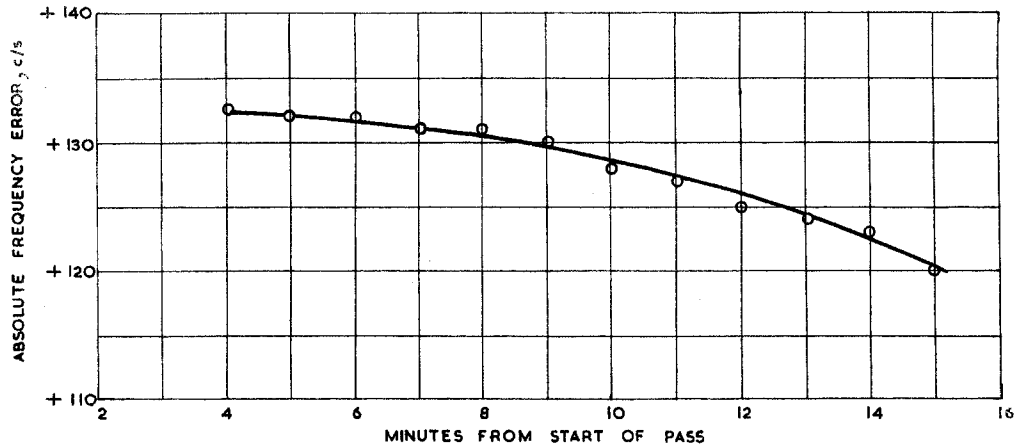

Fig. 3 - Andover-to-Goonhilly circuit via Telstar satellite.
Error in frequency of colour subcarrier received
at Goonhilly during pass No. 88

frequency, are changed slightly. A special broadcast of the type suggested, therefore, is unlikely to be suitable for simultaneous broadcasting on both sides of the Atlantic.

In the event of a shared broadcast on a common standard, it would be necessary to include, in the link circuit, some form of compensation for the Doppler effect; this could consist of a variable delay device such as a magnetic drum store.

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